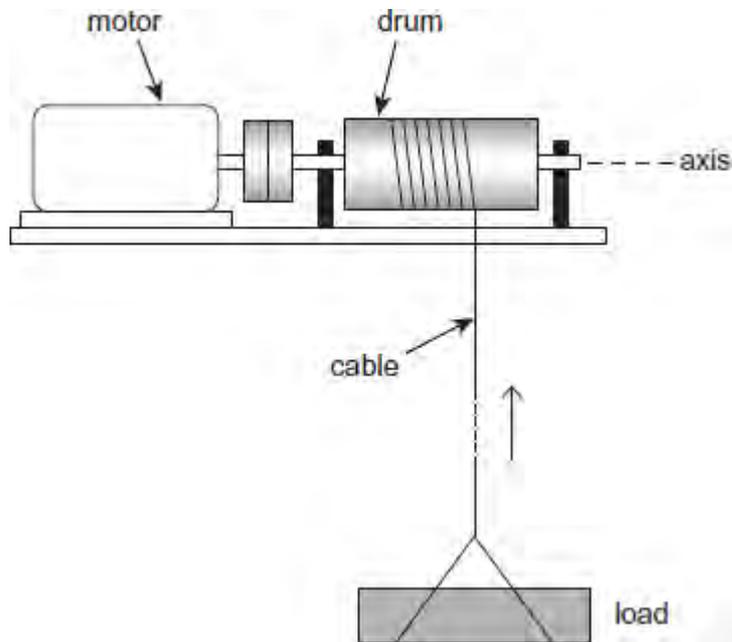**Q1.** The following figure shows a motor-driven winch for raising loads on a building site. As the motor turns the cable is wound around the drum, raising the load.

The drum, axle and other rotating parts have a moment of inertia about the axis of rotation of 7.4 kg m^2, and the mass of the load is 85 kg. The drum has a radius of 0.088 m.

The load is accelerated uniformly from rest to a speed of 2.2 m s^{-1}. When it is accelerating it rises through a height of 3.5 m. It then continues at the constant speed of 2.2 m s^{-1}.

(a)   Show that the drum turns through 40 rad as the load accelerates.

(1)

(b)   Calculate the angular speed of the drum when the load is moving at 2.2 m s^{-1}.

angular speed .... rad s^{-1}

(1)

(c) (i)   Show that for the time that the load is accelerating the total increase in energy of the load and the rotating parts is about 5400 J.

(3)

(ii)   A constant frictional torque of 5.2 N m acts at the bearings of the winch.

Calculate the total work done by the motor to accelerate the load.

Give your answer to an appropriate number of significant figures.

total work done .... J

(3)

(d) Calculate the **maximum** power developed by the motor.

maximum power .... W

(2)
(Total 10 marks)

Q2. The turntable of a microwave oven has a moment of inertia of 8.2×10^{-3} kg m^2 about its vertical axis of rotation.

(a)   With the drive disconnected, the turntable is set spinning. Starting at an angular speed of 6.4 rad s^{-1} it makes 8.3 revolutions before coming to rest.

(i)   Calculate the angular deceleration of the turntable, assuming that the deceleration is uniform. State an appropriate unit for your answer.

angular deceleration .... unit ....

(4)

(ii)   Calculate the magnitude of the frictional torque acting at the turntable bearings.

torque .... N m

(1)

(b)   The turntable drive is reconnected. A circular pie is placed centrally on the turntable. The power input to the microwave oven is 900 W, and to cook the pie the oven is switched on for 270 seconds. The turntable reaches its operating speed of 0.78 rad s^{-1} almost immediately, and the friction torque is the same as in part (a)(ii).

(i)   Calculate the work done to keep the turntable rotating for 270 s at a constant angular speed of 0.78 rad s^{-1} as the pie cooks.
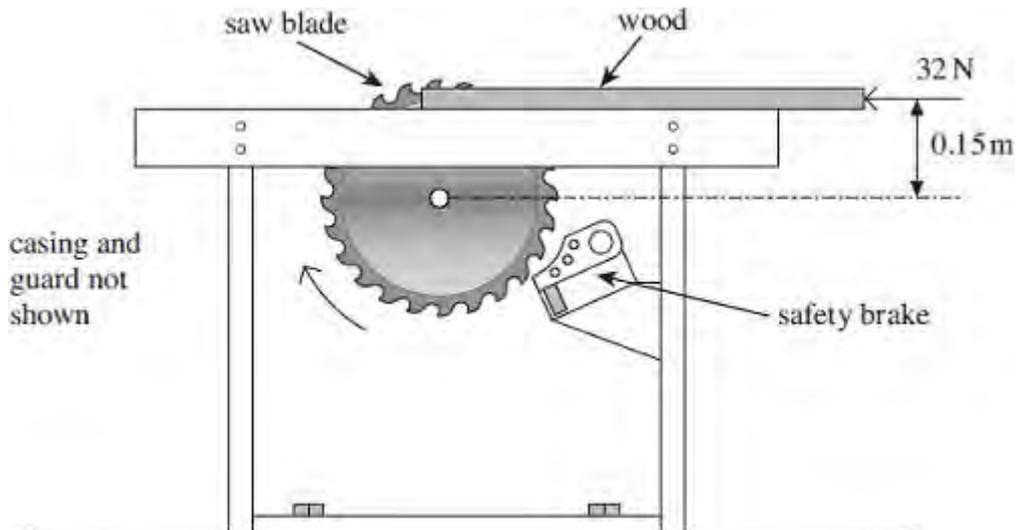
work done .... J

(2)

(ii)   Show that the ratio

$$\frac{\text{energy supplied to oven}}{\text{work done to drive turntable}}$$

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is of the order of 10^5.

(2)
(Total 9 marks)

Q3.   The figure below shows a type of circular saw. The blade is driven by an electric motor and rotates at 2600 rev min^{-1} when cutting a piece of wood. A constant frictional torque of 1.2 Nm acts at the bearings of the motor and axle.

A horizontal force of 32 N is needed to push a piece of wood into the saw. The force acts on the blade at an effective radius of 0.15 m.

(a)   (i)   Calculate the torque on the saw blade resulting from the horizontal force on the wood.

answer = ... Nm

(1)

(ii)   Calculate the output power of the motor when the saw is cutting the wood.

answer = ... W

(3)

(b)   Immediately after cutting the wood the motor is switched off. The time taken for the saw blade to come to rest is 8.5 s. Calculate the moment of inertia of the rotating parts (i.e. the motor rotor, axle and blade). State an appropriate unit.

answer = ... unit = ...

(3)

(c)   If the blade is accidentally touched when it is rotating, an electronic safety brake stops the blade in 5.0 ms. This is fast enough to prevent serious injury. The safety brake works by forcing a block of aluminium into the saw teeth.

Estimate the rate at which the rotational kinetic energy is dissipated as heat and in deforming the aluminium when the brake operates.

answer = ... W

(2)
(Total 9 marks)

Q4.   A grinding wheel is used to sharpen chisels in a school workshop. A chisel is forced against the edge of the grinding wheel so that the tangential force on the wheel is a steady 7.0 N as the wheel rotates at 120 rad s^{-1}. The diameter of the grinding wheel is 0.15 m.

(a)   (i)   Calculate the torque on the grinding wheel, giving an appropriate unit.

answer = ...

(2)

(ii)   Calculate the power required to keep the wheel rotating at 120 rad s^{-1}.

answer = ... W

(1)

(b)   When the chisel is removed and the motor is switched off, it takes 6.2 s for the grinding wheel to come to rest.

Calculate the number of rotations the grinding wheel makes in this time.

answer = ...

(2)
(Total 5 marks)

Q5.Figure 1 shows the *speed regulator fly* of a clockwork musical box movement. When the movement is switched on, a spring accelerates the fly to a high angular speed which then remains constant as the spring unwinds. **Figure 2** shows how the speed of the fly changes over the first 800 ms after switching on.
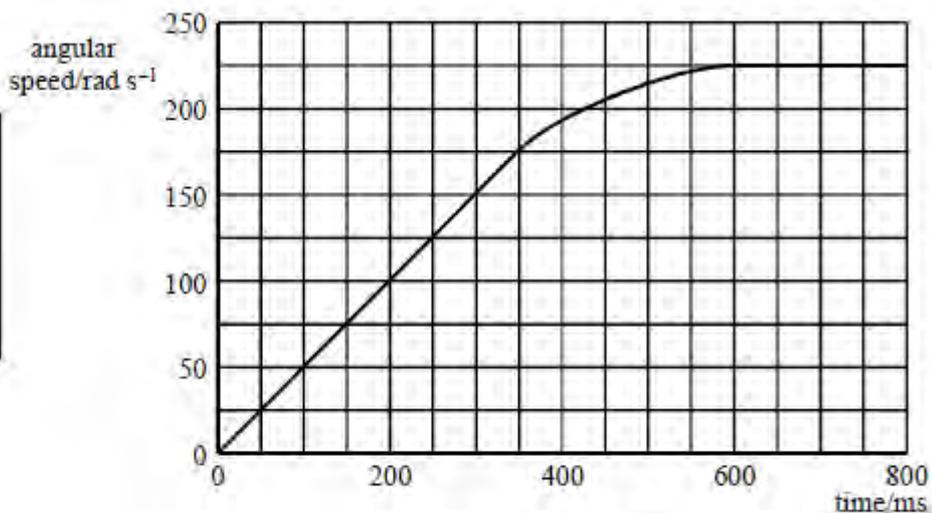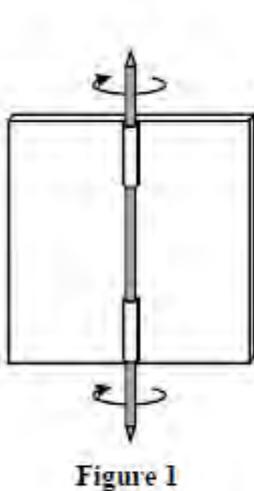
Figure 1

Figure 2

(a)   The fly has a moment of inertia of 4.20×10^{-7} kg m^2.

Calculate

(i)   the angular acceleration of the fly immediately after the movement is switched on,

....

....

....

(ii)   the torque acting on the fly during this initial acceleration.

....

....

(3)

(b)   The torque applied to the fly by the spring is constant during the time it takes the fly to reach its maximum angular speed.

(i)   Explain why the fly initially accelerates uniformly but eventually reaches a steady angular speed.

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(ii) Calculate the power which the spring must supply to keep the fly rotating at a steady angular speed of 225 rad s^{-1}.

....

....

....

(iii) Estimate the energy which the spring supplies to keep the fly rotating at 225 rad s^{-1} for 1 minute.

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....

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(5)
(Total 8 marks)